

The Distribution of Annonaceae and Myristicaceae on Singapore Island

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Introduction

Between the years of 1956 and 1959 a great deal of activity was centered in the University of Malaya in Singapore on the "Phytochemical Survey of Malaya". The Departments of Botany and Chemistry together with the Department of the Protector of Aborigines, Federation of Malaya, accumulated a collection of reputed native drug plants, identified these and processed them for alkaloids and other products.

Douglas and Kiang (1957) report the results of tests on 214 species of plants collected around Singapore and Malaya. Kiang, Douglas and Morsingh (1961) report on a further 708 species belonging to 104 families and 408 genera.

The survey was largely in botanical terms *ad hoc*, and consequently it was resolved that, on the first available opportunity, a survey with special reference to defined taxonomic groups and a limited area of land would be undertaken.

The present survey is the first attempt of its kind along these lines. Two tropical families of plants, the *Annonaceae* and the *Myristicaceae* were chosen. These families have been recently revised by Sinclair (1955, 1958, 1961). With the continued presence of Mr. Sinclair at the Botanic Gardens, Singapore, taxonomic problems could be dealt with expeditiously. Again, in the two reports of tests made by Douglas and Kiang (1957) and Kiang, Douglas and Morsingh (1961) a number of annonaceous plants was found to give strong positive tests for alkaloids. Information regarding the distribution and amount of the two families within Singapore Island was sought. By amount is meant the number of plants (classified according to their respective stem diameters at breast height) existing, as well as the amount of air-dried plant materials (in the form of leaves, stem, bark, etc.) that can be got. This knowledge is basic for ecological and phytochemical assessment.

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The members of these two families are typically forest plants, and the island, after more than a century of colonisation, is devoid of any natural vegetation save 4,805 acres of now-protected forests. Of these 4,805 acres, only 163 acres at Bukit Timah are anywhere near the original condition. The present situation can be traced to the pepper and gambier cultivation and timber and firewood exploitation prevalent in those early years (Wee, 1964).

Materials and Methods

The survey was conducted in two parts:

- (i) The areas outside the Nature Reserves.
- (ii) The areas gazetted as Nature Reserves.

The method adopted in the survey of the 129,286 acres of land outside the Nature Reserves was one of reconnaissance. For such a survey a detailed map of the Island (scale 1:25,000) and a "Singapore Guide and Street Directory" (1961 edition) were of great help. The main roads were used as the base of the exploration from which subsidiary roads and paths were traversed. The surrounding areas were examined for existing annonaceous and myristicaceous plants — cultivated or otherwise. The exact locality and the number of trees were noted. The distribution of the major species existing outside the Nature Reserves was later plotted.

The various areas of protected forests were visited and the presence or absence of the relevant plants was noted. Of these areas the 4,006 acres of the Water Catchment area however proved a problem. This large mass of forest consists of a mixture of vegetational types. A general view of the area from any one point on the island is not possible. In this respect, aerial photographs proved useful. These stereo-prints (taken by the R.A.F. in 1955) helped in the differentiation of a number of vegetational types. Visits to various parts of the area were made to confirm conclusions drawn from the photographs.

The relevant areas were sampled after the method of Gilliland and Wantman (1959). A surveyor's chain of 100 feet was laid on the ground in the forest. Annonaceous and myristicaceous plants occurring to within 3 feet of either side of the chain were noted and classified according to their diameter at breast height (dbh). A throw thus made up 600 sq. ft., and a sample consisting of 10 throws gave a total area of 6,000 sq. ft.

The size of each plant with respect to an arbitrary chosen one was also noted. The dry weights of the leaves, stem and bark (in the case of trees) of the chosen plants were later found by air drying them for about a week before weighing. An estimate of the total dry weights of the parts concerned for the commoner species within the vegetational types were then made.

Results and Discussions

The survey of the 129,286 acres outside the Nature Reserves unearthed a very limited number of relic native annonaceous and myristicaceous species (Fig. I). However, two introduced species, **Annona muricata* and *Cananga odorata* were found to be abundant.

A. muricata was brought into the country during the last century from Tropical America. It is planted extensively throughout the island, especially in Jurong, for its delicious fruits. In most cases it exists as a minor fruit crop among papaya, rambutan, Jack fruit, guava, etc. A total of 3,642 plants were actually counted during the survey (Fig. II).

C. odorata was introduced into this region also through cultivation. It is of Malesian origin, probably originating from the Philippines and Java (I.H. Burkill, 1935). It is a favourite village tree, especially among the Malays, who delight in the fragrant flowers. Also, it used to be a favourite wayside tree. A total of 452 plants were observed, scattered singly or in small groups throughout the island (Fig. III). The distribution is closely associated with man. Within the rural areas, it is most common in kampongs. Its occurrence within the urban areas is centered around the older inhabited sections like Geylang, Balestier Road and Grange Road areas.

It is significant that of the 452 plants observed, only 38 were saplings and 45 were seedlings. Of these seedlings, 42 were found within a piece of abandoned land along Scotts Road. This large number of seedlings is related to the presence of 13 mature trees serving as a large "seed reservoir". Further development of these seedlings was prevented by the periodical clearing of the undergrowth in this area. The other 3 seedlings and the 38 saplings were tenderly cared for in kampongs. Thus taken from its natural habitat and introduced into this region, *C. odorata* has been successful only when man gives a helping hand.

* The nomenclature of annonaceous and myristicaceous members is after Sinclair, 1955, 1958 and 1961.

The 4,805 acres of protected forests consist of the following:

		<i>Acres</i>
(i) Bukit Timah Nature Reserve		184
(ii) Kranji Nature Reserve		51
(iii) Pandan Nature Reserve		542
(iv) Labrador Nature Reserve		11
(v) Water Catchment Area		4,006
(vi) Jungle at Botanic Gardens		11
		4,805

Only the Bukit Timah Nature Reserve, the Water Catchment area and the jungle at the Botanic Gardens were found to contain annonaceous and myristicaceous plants. Within these areas four vegetational types were found to support the above plants. They are as follows:

(i) Belukar Tua — or the more advanced belukar stages. The vegetation consists mainly of poles of dbh varying from 0.5 to 3.0 inches or more. The canopy is in the early stages of closing. Undergrowth is light.

(ii) Regenerating High Forest: This stage is characterised by the presence of isolated high forest trees, often reaching a dbh (or above buttress) of 2 feet or more. These tropical dendrons are commonly members of the *Dipterocarpaceae* (Gilliland and Wantman, 1959).

(iii) Regenerating Swamp Forest: as with Regenerating High Forest.

(iv) High Forest: of unexploited original vegetation with a *Dipterocarpaceae* family dominance (Richards, 1957). It is also typified by the presence of numerous tropical dendrons, a closed canopy and a sparse undergrowth.

A total of 17 transects were taken from representative Belukar Tua types. Two samples were taken from the High Forest at Bukit Timah, one from the Regenerating Swamp Forest at Nee Soon and 10 samples from 10 different "pockets" of Regenerating High Forest found within the Water Catchment area. Samples from the Regenerating Forests and from the High Forest areas are grouped together for purposes of analysis. They are henceforth termed "Regenerating Forests".

Table I: Summarised results of the 17 transects taken from representative Belukar Tua areas

Species	DIAMETER CLASSES						Total	OvB
	S	0-1	1-3	3-5	5-7	over 7"		
Pyramidanthe prismatica ..	135	106	..	..	..	..	241	17/17
Mitrella kentii ..	119	133	..	..	..	..	252	15/17
Xylopia ferruginea ..	128	138	15	9	2	10	302	14/17
Artabotrys suaveolens ..	61	86	..	..	..	..	147	13/17
Fissistigma latifolium ..	103	82	..	..	..	..	185	12/17
Fissistigma fulgens ..	11	13	..	..	..	..	24	8/17
Xylopia fusca (?) ..	22	16	..	..	..	..	38	6/17
Oxymitra latifolia ..	7	9	..	..	..	..	16	6/17
+Knema communis ..	6	7	2	..	..	..	15	6/17
Xylopia malayana ..	10	12	..	..	..	..	22	4/17
Fissistigma manubriatum ..	8	3	..	..	..	..	11	3/17
+Knema latericia ..	3	2	..	..	..	..	5	3/17
+Knema laurina ..	1	3	..	..	..	..	4	3/17
+Knema malayana ..	1	2	..	..	..	..	3	3/17
Polyalthia rumphii ..	1	3	..	..	..	..	4	3/17
Cyathocalyx ramuliflorus ..	0	1	1	1	..	..	3	3/17
Desmos dasymaschalus ..	4	3	..	..	..	..	7	2/17
Cyathocalyx ridleyi ..	..	4	1	..	..	1	6	2/17
Oxymitra sp. 1 ..	1	3	..	..	..	..	4	2/17
Oxymitra biglandulosa ..	..	3	..	..	..	..	3	2/17
Uvaria cordata ..	..	2	..	..	..	..	2	2/17
+Knema intermedia ..	..	1	1	..	..	..	2	2/17
+Gymnacranthera forbesii ..	5	9	..	..	..	..	14	1/17
Oxymitra glauca ..	..	10	..	..	..	..	10	1/17
+Horsfieldia subglobosa ..	..	1	1	..	..	..	2	1/17
+Horsfieldia grandis ..	..	1	1	..	..	..	2	1/17
Fissistigma lanuginosum ..	..	1	..	..	..	..	1	1/17
Phaeanthus ophthalmicus ..	..	1	..	..	..	..	1	1/17
Polyalthia angustissima ..	..	..	1	..	..	..	1	1/17
+Knema cinerea var. patentinervia ..	..	..	1	..	..	..	1	1/17
+Gymnacranthera bancana ..	..	..	1	..	..	..	1	1/17
Total ..	626	655	25	10	2	11	1,329	..

Note:— (+) = Members of the = *Myristicaceae*.

S=Seedlings.

OvB=the number of transects out of 17 in which a species occurs.

Table II: Summarised results of the 13 transects taken from areas of Regenerating High Forest, Regenerating Swamp Forest and High Forest

Species	DIAMETER CLASSES						Total	OvB
	S	0-1	1-3	3-5	5-7	over 7"		
—Fissistigma latifolium ..	25	49	..	..	..	..	74	13/13
—Oxymitra latifolia ..	16	32	..	..	..	..	48	11/13
±Knema latericia ..	2	13	13	1	..	1	30	11/13
Popowia fusca ..	16	36	5	1	..	..	58	10/13
—Polyalthia rumphii ..	..	35	7	..	..	..	42	10/13
—Cyathocalyx ramuliflorus ..	2	4	9	4	4	7	30	10/13
—Phaeanthus ophthalmicus ..	15	48	5	..	..	..	68	9/13
±Knema laurina ..	11	48	8	..	..	..	67	9/13
±Knema malayana ..	5	19	6	1	..	..	31	9/13
Polyalthia cauliflora ..	..	22	6	..	..	..	28	9/13
—Fissistigma fulgens ..	8	18	..	..	..	..	26	8/13
±Gynacranthera forbesii ..	4	19	2	..	..	..	25	8/13
Cyathostemma viridiflorum ..	8	12	..	..	..	..	20	8/13
—Polyalthia augustissima ..	..	12	3	..	..	..	15	8/13
—Cyathocalyx ridleyi ..	4	33	18	5	6	11	77	7/13
±Knema communis ..	4	17	7	1	..	..	29	7/13
+Knema hookeriana ..	1	4	12	1	2	3	23	7/13
—Horsfieldia subglobosa ..	..	7	8	1	2	..	18	7/13
—Mitrella kentii ..	7	32	..	..	..	..	39	6/13
—Pyramidanthe prismatica ..	9	25	..	..	..	..	34	6/13
—Xylopi ferruginea ..	..	12	1	2	2	..	17	6/13
—Fissistigma lanuginosum ..	4	13	..	..	..	..	17	6/13
—Xylopi malayana ..	4	12	..	..	..	..	16	6/13
—Desmos dasymaschalus ..	3	16	..	..	..	..	19	5/13
Polyalthia glauca (?) ..	1	9	..	..	..	..	10	5/13
—Artabotrys suaveolens ..	3	6	..	..	..	..	9	5/13
Popowia pisocarpa ..	..	6	2	..	..	..	8	5/13
Carried forward ..	152	559	112	17	16	22	1,878	..

Table II—continued

Species	DIAMETER CLASSES						Total	OvB
	S	0-1	1-3	3-5	5-7	over 7"		
<i>Brought forward</i> ..	152	559	112	17	16	22	1,878	
± <i>Gymnacranthera bancan</i> ..	..	2	5	1	..	..	8	5/13
± <i>Knema intermedia</i> ..	12	53	14	1	1	..	81	4/13
+ <i>Horsfieldia wallichii</i> ..	..	16	8	1	1	..	26	4/13
— <i>Oxymitra</i> sp. I ..	3	23	..	..	..	..	26	4/13
+ <i>Gymnacranthera eugeniifolia</i> var. <i>eugeniifolia</i> ..	2	12	..	..	..	..	14	4/13
— <i>Uvaria cordata</i> ..	..	4	..	..	..	..	4	4/13
<i>Goniothalamus</i> sp. ..	..	7	..	..	..	..	7	3/13
+ <i>Knema conferta</i> ..	..	1	1	1	1	..	4	3/13
+ <i>Gymnacranthera eugeniifolia</i> var. <i>griffithii</i> ..	..	8	1	..	..	..	9	2/13
+ <i>Horsfieldia crassifolia</i> ..	..	1	4	..	..	..	5	2/13
— <i>Oxymitra glauca</i> ..	..	5	..	..	..	..	5	2/13
— <i>Xylopia fusca</i> (?) ..	1	3	1	..	..	..	5	2/13
<i>Polyalthia</i> sp. ..	..	4	..	..	1	..	5	2/13
+ <i>Myristica elliptica</i> ..	..	3	1	..	..	..	4	2/13
— <i>Fissistigma manubriatum</i> ..	..	3	..	..	..	..	3	2/13
— <i>Oxymitra biglandulosa</i> ..	..	3	..	..	..	..	3	2/13
<i>Alphonsea maingayi</i> ..	..	..	1	..	2	..	3	2/13
<i>Polyalthia sumatrana</i> ..	..	2	..	..	..	..	2	2/13
<i>Anaxagorea javanica</i> ..	35	33	4	..	..	..	72	1/13
<i>Goniothalamus ridleyi</i> ..	..	..	3	1	..	..	4	1/13
<i>Polyalthia laterifolia</i> ..	..	3	..	..	..	..	3	1/13
<i>Meiogyne virgata</i> ..	..	2	1	..	..	..	3	1/13
+ <i>Horsfieldia superba</i> ..	..	..	1	1	..	..	2	1/13
<i>Artabotrys costatus</i> ..	..	1	..	..	..	..	1	1/13
<i>Artabotrys wrayi</i> ..	..	1	..	..	..	..	1	1/13
<i>Oxymitra</i> sp. II ..	..	1	..	..	..	..	1	1/13
<i>Polyalthia macropoda</i> ..	..	..	1	..	..	..	1	1/13
± <i>Horsfieldia grandis</i> ..	..	..	1	..	..	..	1	1/13
+ <i>Myristica iners</i> ..	..	1	..	..	..	..	1	1/13
+ <i>Myristica cinnamonea</i> ..	..	1	..	..	..	..	1	1/13
Total ..	205	752	159	23	22	22	1,183	..

Note:— (+) = Members of the *Myristicaceae*.

(−) = Species also found within Belukar Tua areas.

OvB = the number of transects out of 13, in which a species occur.

TABLE III.—Total number of species and plants found within the two main vegetational types

<i>Belukar Tua</i> :	<i>Annonaceae</i>	<i>Myristicaceae</i>	Total
Species ...	21	10	31
Genera ...	11	3	14
Plants/Transect ...	76.2	2.9	79.1
<i>"Regenerating Forest"</i> :			
Species ...	38	18	56
Genera ...	17	4	21
Plants/Transect ...	61.8	29.2	91.0

The distributions of the commoner species were tested against the Poisson series for randomness (Blackman, 1935; Clapham, 1936; Archibald, 1948). The results of the analysis are presented in Tables IV and V.

TABLE IV

Poisson test for randomness as applied to the more abundant *Annonaceae* and *Myristicaceae* members found within the Belukar Tua areas.

	<i>Pyramidanthie prismatica</i>			<i>Mitrella kentii</i>			<i>Xylople ferruginea</i>			<i>Artabotrys suaveolens</i>			<i>Fissistigma latifolium</i>		
	OBS.	EXP.		OBS.	EXP.		OBS.	EXP.		OBS.	EXP.		OBS.	EXP.	
0*	92	41.09		81	38.73		90	27.81		113	71.57		123	57.12	
1	41	58.34		40	57.26		24	50.34		30	61.91		21	62.39	
2	12	41.43		15	42.36		19	45.56		12	26.78		6	34.00	
3	8	19.60		8	20.91		10	27.49		5	7.72		4	12.24	
4	4	6.95		8	7.74		5	12.44		5	1.67		1	3.40	
5	2	1.97		7	2.30		4	4.51		1	0.29		6	0.68	
6	1	0.48		4	0.56		6	1.36		—	0.03		2	0.16	
7	3	0.10	9.523	1	0.12	10.74	2	0.36	6.34	—	—	9.71	0	0.01	16.49
8	2	0.02		2	0.02		4	0.09		2	—		1	—	
9	1	0.003		2	—		—	0.02		—	—		2	—	
≥ 10	4	—		2	—		6	—		2	—		4	—	
	170	169.983		170	170.00		170	169.98		170	169.97		170	170.00	
	x ² =	101.85		x ² =	79.00		x ² =	222.25		x ² =	51.47		x ² =	127.25	
	P <	0.001		P <	0.001		P <	0.001		P <	0.001		P <	0.001	

*Note: The first column gives the number of plants per sample of 600 square feet.
OBS. = Observed;
EXP. = Expected.

TABLE V

Poisson test for randomness as applied to the more abundant *Annonaceae* and *Myristicaceae* members found within the Regenerating and High Forest areas.

<i>Fissistigma latifolium</i>			<i>Oxymitra latifolia</i>			<i>Knema laurina</i>			<i>Mitrella kentii</i>		
OBS.	EXP.		OBS.	EXP.		OBS.	EXP.		OBS.	EXP.	
0*	85	73.58	103	89.87		97	77.66		108	96.30	
1	26	41.85	16	33.16		18	40.00		12	28.89	
2	13	11.91	4	6.12		7	10.30		6	4.33	
3	3	2.26	5	0.75	6.95	3	1.77	12.23	1	0.43	4.80
4	2	0.32	1	0.07		1	0.23		3	0.04	
≥5	1	0.04	1	0.01		4	0.03		—	—	
	130	129.98	130	129.98		130	129.99		130	129.99	
x2	= 9.18		x2	= 12.93		x2	= 17.50		x2	= 16.93	
P	< 0.01		P	< 0.001		P	< 0.001		P	< 0.001	

<i>Popowia fusca</i>			<i>Polyalthia rumphii</i>			<i>Cyathocalyx ridleyi</i>			<i>Phaeanthus ophthalmicus</i>		
OBS.	EXP.		OBS.	EXP.		OBS.	EXP.		OBS.	EXP.	
0	105	83.24	106	94.12		101	71.93		103	77.05	
1	20	37.13	16	30.41		13	42.59		16	40.31	
2	2	8.28	4	4.91		4	12.60		6	10.56	
3	—	1.23	1	0.53	5.48	6	2.48	15.48	1	1.83	12.64
4	—	0.14	1	0.04		2	0.36		—	0.25	
≥5	3	0.01	2	—		4	0.04		4	—	
	130	130.03	130	130.01		130	130.00		130	130.00	
x2	= 15.83		x2	= 9.47		x2	= 20.79		x2	= 23.65	
P	< 0.001		P	< 0.01		P	< 0.001		P	< 0.001	

*Note: The first column gives the number of plants per sample of 600 square feet, OBS. = Observed, EXP. = Expected.

Allowance was made to group the values together so that no expected value is less than 5 (after Greig-Smith, 1957). This arbitrary level is that commonly used in calculations of Chi square (χ^2) to eliminate the disproportionate effect of small differences from a low expectation. The total value of χ^2 is entered in the table with degrees of freedom two less than the number of values from which χ^2 is calculated, one degree of freedom being used in the determination of the mean. The limit of P chosen, beyond which the agreement is too poor to substantiate the hypothesis is 0.05 (after Blackman, 1935).

The analysis of the more common species shows conclusively that the individuals of these species occurring within their respective communities are distributed non-randomly (Table IV and V). The rarer species were not examined. Their limited existence made it impossible to use the Chi-square tests. A direct consequence of this non-random distribution is that the mean density of a species cannot be estimated with useful accuracy from its frequency index. Thus the dry weights of the various parts of the commoner species as given in Table VI are *strictly estimations*.

TABLE VI.—The amount of plant parts available for the commoner species of *Annonaceae* and *Myristicaceae*

(Note that the amounts are derived through estimations)

Air-dried Weights in Kilograms/Acre				
<i>Belukar Tua:</i>		Leaves	Twigs	Bark
<i>Artabotrys suaveolens</i>	...	0.6	1.0	—
<i>Fissistigma latifolium</i>	...	0.2	0.6	—
<i>Knema communis</i>	...	0.4	0.6	—
<i>Mitrella kentii</i>	...	0.6	1.2	—
<i>Pyramidanthe prismatica</i>	...	0.8	1.2	—
<i>Xylopia ferruginea</i>	...	92.8	324.8	162.7
<i>Regenerating and High Forest:</i>				
<i>Cyathocalyx ridleyi</i>	...	153.1	358.2	152.5
<i>Fissistigma latifolium</i>	...	0.1	0.4	—
<i>Knema communis</i>	...	4.2	11.1	2.2
<i>Knema laurina</i>	...	1.8	2.7	—
<i>Mitrella kentii</i>	...	0.1	0.1	—
<i>Oxymitra latifolia</i>	...	0.6	0.9	—
<i>Phaeanthus ophthalmicus</i>	...	1.3	1.8	—
<i>Polyalthia rumphii</i>	...	1.9	4.2	—
<i>Popowia fusca</i>	...	1.3	12.3	—

Note:—*Knema communis* is specially included here although its occurrence is low because it has been found to contain some interesting alkaloids.

The results from the survey of the 4,805 acres of protected forests clearly show that the *Annonaceae* and *Myristicaceae* are forest plants. The myristicaceous plants in particular demand a forest habitat. A total of 18 species were encountered from regenerating and high forest areas, with a mean of 29.2 plants per transect of 6,000 sq. feet. This is contrasted to the ten species found within the Belukar Tua areas. In this case the mean number of plants per transect was only 2.9 (Table III). Again, most of the Belukar Tua occurrences were of the 0-1" dbh category and found only within the more advanced Belukar Tua areas. Only when the canopy was closed with an absence of undergrowth did they occur.

The annonaceous plants on the other hand, equally tolerate the Belukar Tua as well as the Regenerating Forest. Although the density is more or less the same, the number of species increases in the Regenerating Forest habitats.

It is of interest to note that five annonaceous species viz: *Pyramidanthe prismatica*, *Mitrella kentii*, *Xylopia ferruginea*, *Artabotrys suaveolens* and *Fissistigma latifolium* stand out as the important members of the Belukar Tua areas (Table I). The rest of the 26 species form the casual members of the community. Of these five species, *F. latifolium* plays a major role in the Regenerating Forest community also. It should be noted further that of the 31 species encountered within the Belukar Tua areas, only *Knema cinerea* var. *patentinervia* was absent from the Regenerating Forest areas. A total of 26 more species were encountered in the latter community.

The distribution of members of the two families is not uniform within the two communities. *P. prismatica* was found in all 17 transects taken from Belukar Tua areas; *F. latifolium*, in all 13 transects from the Regenerating Forest areas. The other species were encountered in a rather erratic fashion. Of the 31 species from the Belukar Tua samples and 56 species from the Regenerating Forest samples, only five and eight species respectively occur with a high enough frequency to be tested for the Poisson distribution. Of these 11 species* tested, all showed a significantly non-random distribution, with a tendency towards clumping.

Clapham (1936) is of the opinion that clumping is a widespread phenomenon. Of the 44 species he investigated, only four were found to conform to the Poisson distribution. Blackman (1935), on the other hand, expresses the opinion that the dominant species in most cases approximates to a normal distribution curve.

* *Fissistigma latifolium* and *Mitrella kentii* occur in both communities.

Skewness is greater for occasional species and greatest for rarer species. These authors believe that the mode of reproduction has a direct effect on the distribution of the plant. Where reproduction is by seed, random distribution is to be expected. This is contrasted to vegetative reproduction as a cause of non-random distribution. Archibald (1948), takes the argument a step further by saying that random distribution would occur where single seeds are dispersed by wind or water. In cases of animal or bird dispersal, particularly where the fruit contains several seeds, it is highly probable that a fruit, when carried away, would result in a number of individuals subsequently arising in a cluster.

Such is the case with the *Annonaceae*, where the fruit contains several seeds, and distribution is by animals — squirrels, civet cats, bats and birds. The *Myristicaceae* is also animal disperse, although each fruit carries only one seed. Thus with animal dispersal, the distribution of the plants concerned depends on the habits of the agents.

An excellent example is afforded by *Cyathocalyx ridleyi*. The species is concentrated in three main areas of Regenerating High Forest. The existence of representatives from each of the various diameter classes within the three localities suggests successful regeneration. Of the 77 plants encountered in seven areas, 67 plants were seen from these three areas. One may well ask why *C. ridleyi* is not more widely distributed, considering the fact that it is successfully regenerating itself. Again, it is now about 100 years since the first of the Catchment block was put under control (H.M. Burkill 1961), and within this period of time surely the plant ought to have spread more extensively. Why this is not so is still a puzzle. The plant is mainly distributed by squirrels, which tend to scatter the seeds around the base of the parent plant. It is possible that its distribution follows in some way the distribution of the squirrel.

Such a situation is also found in *Knema intermedia*, where two areas of Regenerating High Forests revealed a total of 79 plants.

Anaxagorea javanica is found in Singapore only at the Botanic Gardens' jungle. It grows profusely within a limited area, regenerating successfully. The reason why it has not been successful in escaping from this locality can be seen from its mode of dispersal. The fruits are follicles. Each follicle contains two hard, black shiny seeds pressed together. The ripe follicle splits open and then suddenly contracts as it dries so as to eject the seeds with a click. In this respect it behaves as a capsule. The seeds can be shot out to a distance of two to three yards, not far enough to spread successfully.

Popowia fusca is present in large numbers at the Taban Circle area, Bukit Timah Nature Reserve. A sample of 6,000 square feet recorded a total of 40 plants, all within the 0-1" dbh category. None of these were capable of reproducing. Probably a number of seed plants existed nearby. Within the same area, aggregations of *Phaeanthus ophthalmicus* and *Knema laurina* were also encountered.

It thus seems that each of the isolated pockets of Regenerating Forests supports its own favoured species. The isolated nature of these pockets which are surrounded by younger communities may in some way hinder the spread of these species.

During the course of this survey a total of 39 and 21 native annonaceous and myristicaceous species respectively were recorded in the areas covered by the transects. This is a little more than half the total species of these families recorded from Singapore (Sinclair, 1955, 1958). This difference is no surprise, considering the fact that the members of these two families are essentially forest plants, and today, only 3.6% of the island is forested.

Summary

1. Since the establishment of a trading post and settlement in 1819, Singapore has experienced an almost complete change in its vegetation.
2. The present survey is an attempt to gather information regarding the amount and distribution of *Annonaceae* and *Myristicaceae* left on the island.
3. The survey of the 129,286 acres of non-forested areas uncovered the distribution of two common introduced species — *Cananga odorata* and *Annona muricata*.
4. *C. odorata* is closely associated with the Malays and *A. muricata* with the Chinese.
5. Of the 4,805 acres of protected forests, only Bukit Timah Nature Reserve, the Water Catchment area and the jungle at the Botanic Gardens support any of these plants in great number.
6. The myristicaceous plants are typically a High Forest family. The annonaceous plants on the other hand tolerate the Belukar Tua as well as the Regenerating and High Forest habitats.
7. Members of these families exhibit erratic occurrences and are distributed non-randomly. This is correlated with the habits of the animal dispersal agents.
8. An attempt was made to estimate the availability of air-dried plant materials of the commoner species.

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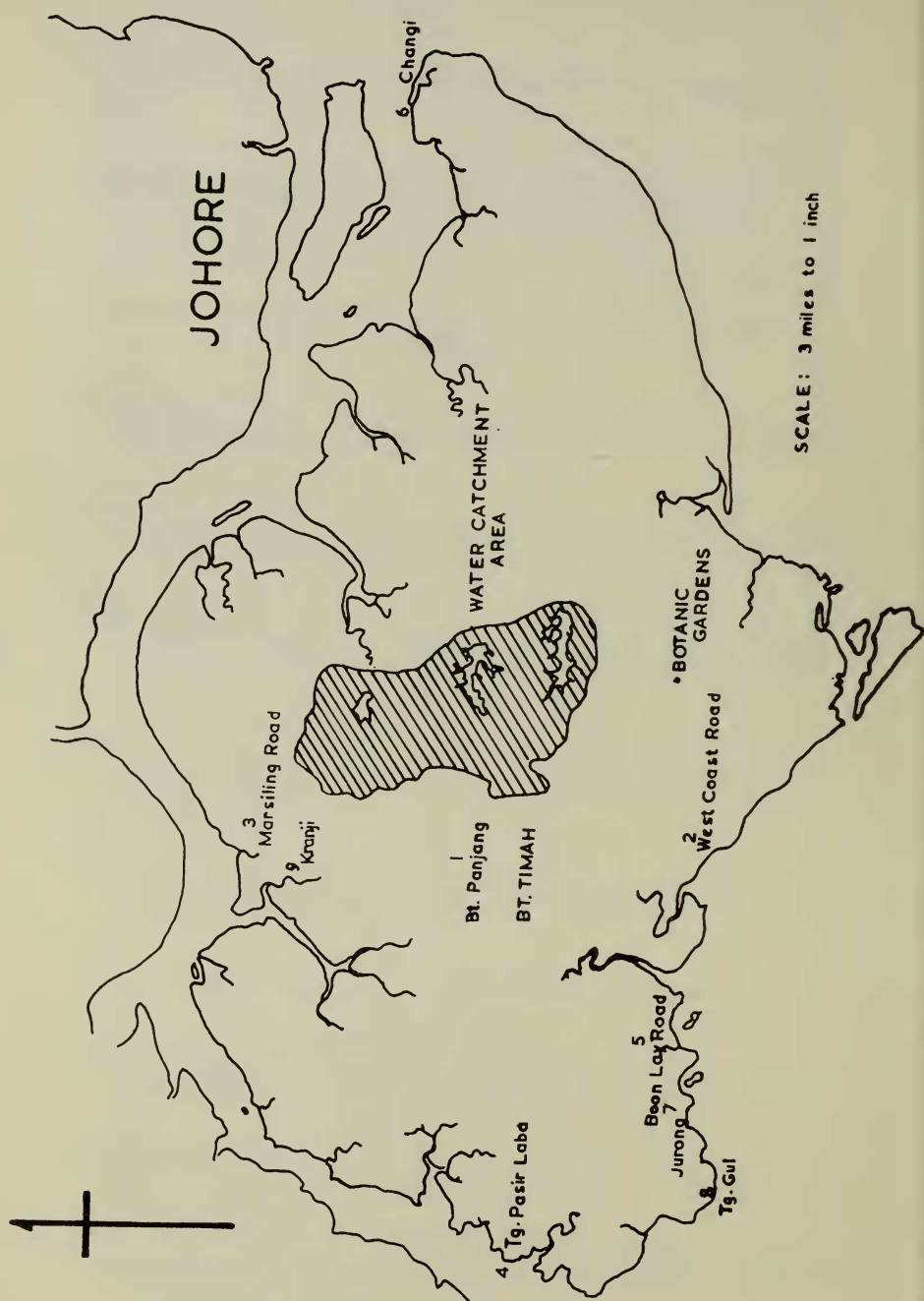
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Fig. 1



The extent of recorded occurrences of native *Annonaceae* and *Myristicaceae*
(Present day)

(See facing page.)

Key:

1. *Uvaria grandiflora*: — flourishing by a path leading up Bukit Panjang.
2. *Uvaria leptopoda*: — off 8th mile West Coast Road (Sinclair, 1955).
3. *Horsfieldia crassifolia*: — 3 trees, along the fringe of farmland at Marsiling Road.
4. *Horsfieldia superba*: — a sapling growing along the coast at Tanjong Pasir Laba (Sinclair, 1958).
5. *Horsfieldia irya*: — 2 trees, along the fringe of farmland at $\pm$ 16 milestone, Boon Lay Road.
6. *Knema globularia*: — 3 trees growing by the coast near Changi Point.
7. An area of a few acres of relic forest at Jurong. Forest thoroughly exploited for firewood. *Phaeanthus ophthalmicus*, *Knema intermedia* and *K. conferta* found within this area.
8. *Knema globularia* and *Myristica iners*: — by the coast at Tanjong Gul (Sinclair, seen October, 1961).
9. *Horsfieldia superba*: — tree, growing at the edge of a swamp at Kranji (Sinclair, seen May, 1965).

The above gives the relics unearthed, the present distribution is concentrated about the central mass of Nature Reserves.



Fig. II

Distribution of *Annona muricata* in Singapore
(See facing page.)

Each DOT represents SIX plants.

1. 900 plants, Tuas area.
2. 1,020 plants, Jurong area.
3. 96 plants, Jurong area.
4. 150 plants, Choa Chu Kang area.
5. 72 plants, Jurong Road, 11½ milestone.
6. 96 plants, Day Road.
7. 336 plants, Bukit Panjang.
8. 114 plants, Geylang Road.

Total number of plants = 3,642.

Fig. III



Distribution of *Cananga odorata* in Singapore
(See facing page.)

Each DOT represents ONE plant.

1. 16 trees, Grange Road area.
2. 20 trees, 42 seedlings, Scotts Road.
3. 11 trees, Thomson Road.
4. 19 trees, Balestier Road.
5. 100 trees, Geylang Road.

Total number of plants = 452.